FUZZY LOGIC METHODOLOGY FOR SHORT TERM LOAD FORECASTING

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Abstract

Load forecasting is an important component for power system energy management system. Precise load forecasting helps the electric utility to make unit commitment decisions, reduce spinning reserve capacity and schedule device maintenance plan properly and it also reduces the generation cost and increases reliability of power systems. In this work, a fuzzy logic approach for short term load forecasting is attempted. Time, temperature and similar previous day load are used as the independent variables for short term load forecasting. Based on the time, temperature and similar previous day load, fuzzy rule base are prepared using mamdani implication, which are eventually used for the short term load forecasting. MATLAB SIMULINK software is used here in this work. For the short term load forecasting, load data from the specific area load dispatch center is considered.

Keywords: *Load forecasting, short term load forecasting, Fuzzy logic, Fuzzy inference system.*

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1. INTRODUCTION

The prime duty of any utility is to provide reliable power to customers. Customer load demand in electric distribution systems is subject to change because human activities follow daily, weekly, and monthly cycles. The load demand is usually higher during the daytime and in evening, when industrial loads are high, lights are on, and lower in late evening and early morning when most of the population is asleep. Estimating the distribution system load expected at some time in the future is an important task in order to meet exactly any network load at whatever time it occurs. The estimation of future active loads at various load buses ahead of actual load occurrence is known as load forecasting. If it is done inappropriately, then the direct effect is on the planning for the future load and the result is the difference of the load that will develop from the planning done for the same, and eventually the entire planning process is at risk.

Therefore, load forecast plays a crucial role in all aspects of planning, operation, and control of an electric power system. It is an important task for operating a power system reliably and economically. So, the need and relevance of forecasting load for an electric utility has become an important issue in the recent past. It is not only important for distribution or power system planning but also for evaluating the cost effectiveness of investing in the new technology and the strategy for its propagation. However, in the deregulated market, load forecasting is of utmost importance. As the utility supply and consumer demand is fluctuating and the change in weather conditions, energy prices increases by a factor of ten or more during peak load, load forecasting is vitally important for utilities. Short-term load forecasting is a helping tool to estimate load flows and to anticipate for the overloading. Network reliability increases if the overloading effects are eliminated in time. Also, it reduces rates of equipment failures and blackouts.

Load forecasting is however not an easy task to perform. First, because the load on consumer side is complex and shows several levels of seasonality: the load at a given hour is dependent on the load at the previous hour as well as on the load at the same hour on the previous day, and also on the load at the same hour on the day with the same quantity in the previous week. Secondly, there are many important externally affecting variables that should be considered, particularly weather related variables [1].

There are large varieties of mathematical methods that are used for load forecasting, the development and improvements of suitable mathematical tools will lead to the development of more accurate load forecasting techniques. The accuracy of load forecasting depends on the load forecasting techniques used as well as on the accuracy of forecasted weather parameters such as temperature, humidity etc. As per the recent trends artificial intelligence methods are the most pronounced for the STLF. From different artificial intelligence methods, fuzzy logic and artificial neural network are the most used. Among the two methods fuzzy logic for STLF is gaining importance nowadays, because of its some distinct advantages over ANN.

2. SHORT TERM LOAD FORECASTING

Short term load forecasting is basically is a load predicting system with a leading time of one hour to seven days, which is necessary for adequate scheduling and operation of power systems. For proper and profitable management in electrical utilities, short-term load forecasting has lot of importance [1].

High forecasting accuracy as well as speed is the two most vital requirements of short-term load forecasting and it is of utmost importance to analyze the load characteristics and identify the main factors affecting the load. In electricity markets, the traditional load affecting factors such as season, day type and weather, electricity price have a complicated relationship with system load [1].

3. BLOCK DIAGRAM AND FLOW CHART

The significance of this paper is to do short term load forecasting for a day ahead by taking into considerations time and weather parameters such as temperature. The classification of the load data is done using fuzzy set techniques.

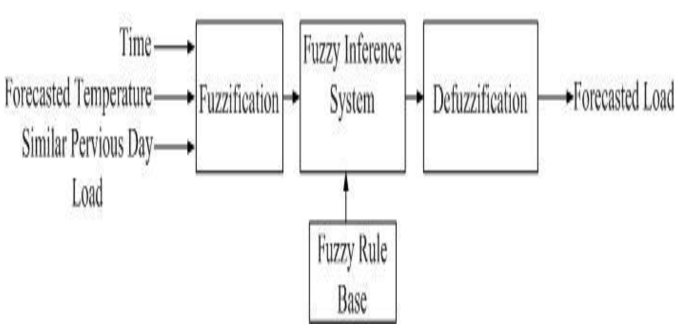

Fig -1: Block diagram of fuzzy logic methodology for short term load forecasting

Figure (Fig -1) shows the basic block diagram of the proposed work. The inputs to the fuzzy set based classifier i.e. hourly data of forecasted temperature and time are given to the fuzzy inference system through fuzzification block. The fuzzy inference block is the heart of the system as it processes the input data and gives output as the forecasted load. The inference system accomplishes the task of forecasting by the used of the fuzzy rule based prepared by the forecaster. The accuracy of the forecast depends on the experience of the forecaster, the rules prepared by the forecaster and the number of rules prepared. After, the inference system gives output; the defuzzification block converts the fuzzified output to the crisp output which can be further displayed on a graph known as the load curve.

Firstly, the historical data are examined and the maximum and the minimum range of different parameters are obtained. These ranges are used in the process of the fuzzification of different parameters such as time and temperature. After the fuzzification is done, based on the different parameter of load forecasting rule are prepared. This rules are the heart of the fuzzy system, so utmost care should be taken to prepare these rules. Once, the rules are prepared forecast the load of the desired hour. Figure (Fig.2) shows the flow chat of STLF using fuzzy logic.

The output obtained is compared with the actual load and the error in load forecasting is used to improve the rule base for future forecast. This improvement in rule of fuzzy logic increases the accuracy of the load forecasting.

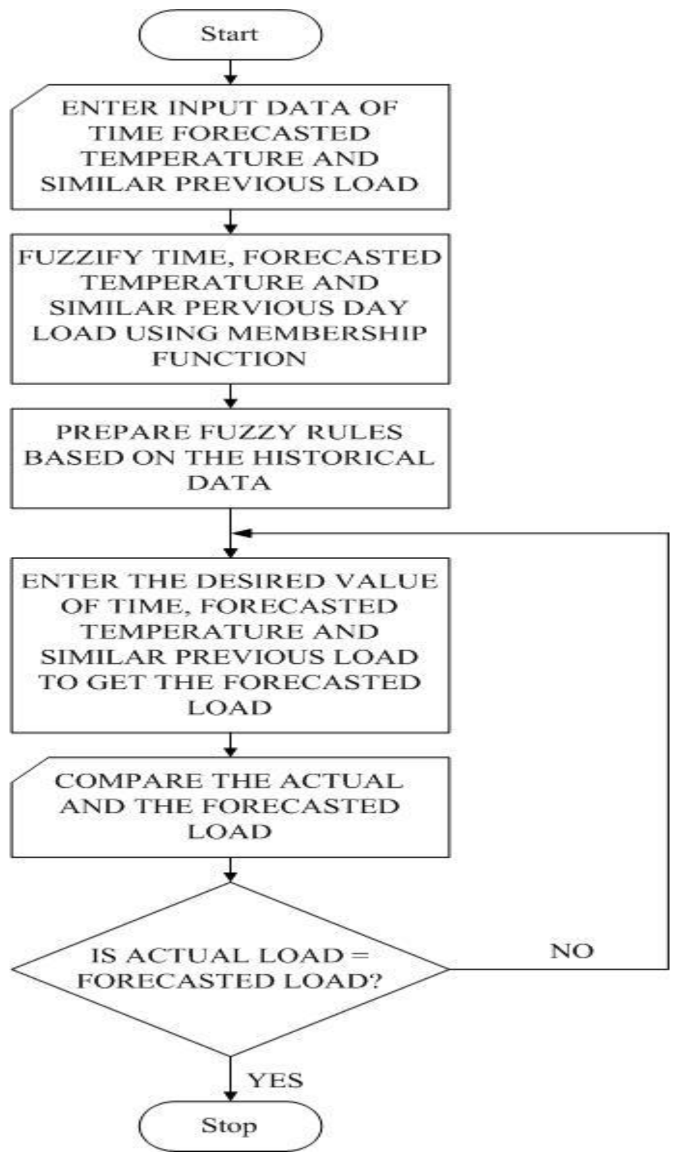

Fig -2: Flow chart of fuzzy logic methodology for short term load forecasting

4. FUZZY LOGIC METHODOLOGY FOR SHORT TERM LOAD FORECASTING

4.1 Fuzzification

Fuzzification is the process of converting crisp numerical values into the degrees of membership related to the corresponding fuzzy sets. A MF will accept as its argument a crisp value and return the degree to which that value belongs to the fuzzy set the MF represents. In order to express the fuzziness of data, this paper makes an arrangement of fuzzy subsets for different inputs and outputs in complete universe of discourse as membership functions. The relationship between several inputs and output may be nonlinear but linear membership functions have been used for simplicity. A rectangular membership function is used for the inputs as well as the output.

The two inputs taken for STLF are Time and Temperature. As shown in figure (Fig -3) time is divided into seven triangular membership functions which are as follows:

- Mid Night (MID-NIG)
- Dawn (DAWN)
- Morning (MORN)
- Noon (NOON)
- Evening (EVE)
- Dusk (DUSK)
- Night (NIGHT)

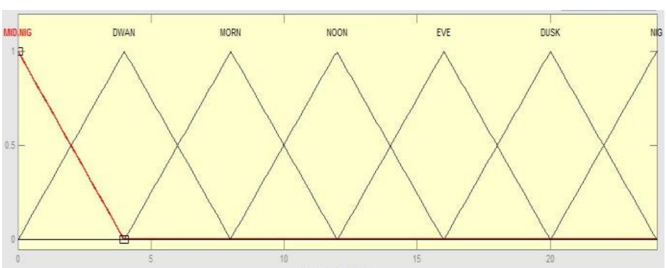

Fig -3: Triangular membership function for time

Figure (Fig -4) shows temperature divided into seven triangular membership functions which are as follows:

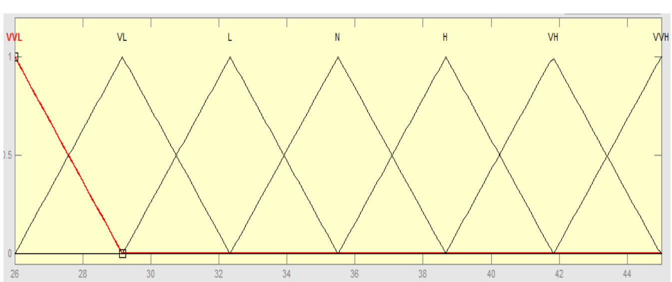

Fig -4: Triangular membership function for forecasted temperature

Figure (Fig -5) shows similar pervious day load divided into seventeen triangular membership functions which are as follows:

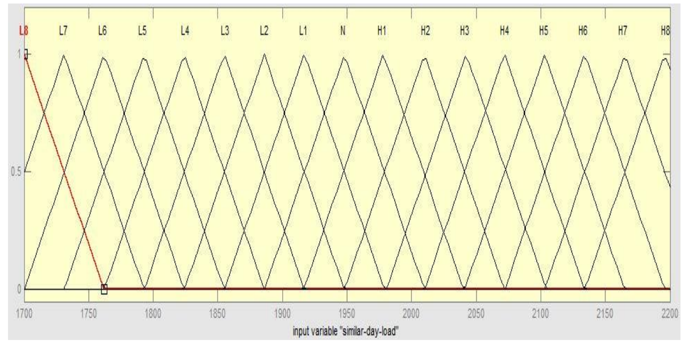

Fig -5: Triangular membership function for similar pervious day load

Figure (Fig -6) shows forecasted load (output) divided into seventeen triangular membership functions which are as follows:

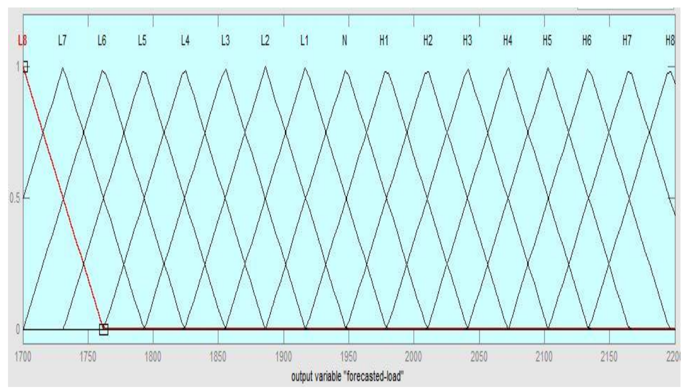

Fig -6: Triangular membership function for forecasted load

4.2 Fuzzy Rule Base

This part is the heart of the fuzzy system. The heuristic knowledge of the forecasted is stored in terms of "IF-THEN" rules. It sends information to fuzzy inference system, which evaluates the gained information to get the load forecasted output. Some of the rules are as follows:

- If (time is MID.NIG) and (forecasted-Temperature is VL) and (similar-day-load is H1) then (forecasted-load is H1) (1)
- If (time is MID.NIG) and (forecasted-Temperature is VL) and (similar-day-load is H2) then (forecasted-load is H2) (1)
- If (time is MID.NIG) and (forecasted-Temperature is VL) and (similar-day-load is H3) then (forecasted-load is H3) (1)

- If (time is MID.NIG) and (forecasted-Temperature is VL) and (similar-day-load is H4) then (forecasted-load is H4) (1)
- If (time is MID.NIG) and (forecasted-Temperature is L) and (similar-day-load is H1) then (forecasted-load is H1) (1)

Similarly, 381 fuzzy rules are prepared based on the data obtained from ALDC, Jambuva, Vadodara

4.3 Simulation Work

Figure (fig -7) shows the simulation of fuzzy logic methodology short term load forecasting. MATLAB is used for the simulation purpose. As shown in the figure (fig -7) the input data's as well as actual load occurred are loaded. The input data are given to fuzzy logic controller block. In fuzzy logic controller block ".fis" of fuzzy inference system is loaded. Based on the rules prepared the fuzzy logic controller give forecasted output corresponding to the input data. Then the permanent shut down block is added. If a substation is in working state for pervious similar day and there is a permanent shutdown for the forecasted day, then the megawatts supplied by the substation need to be subtracted from the forecasted load and vice versa. Thus, final forecast of the day is obtained. Also, the error is calculated along with the forecasting as shown in figure (fig -7).

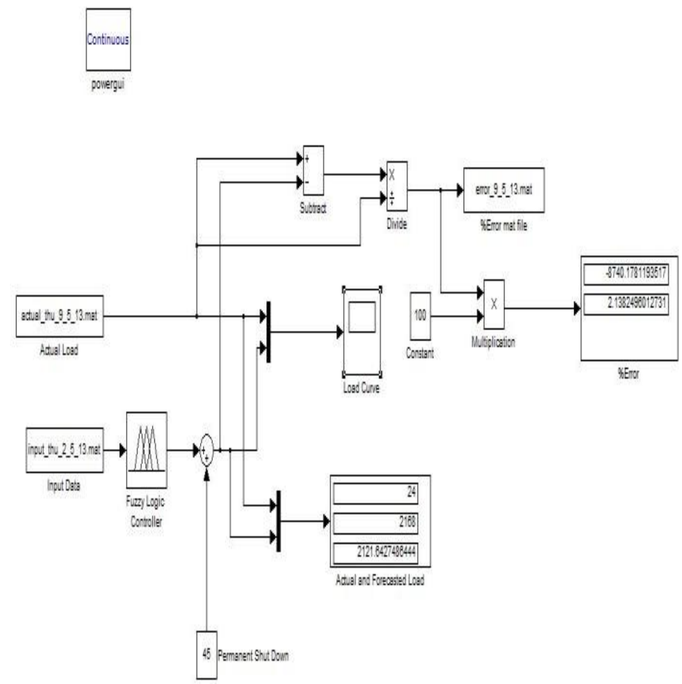

Fig -7: Simulation of short term load forecasting using fuzzy logic in MATLAB

4.4 Results

Table 1 and Table 2 show the actual load, forecasted load and also the percentage error in the forecasted load. The load forecast is done for the day 8th May 2013 and 9th May 2013 respectively. The percentage error in forecast can be calculated as

$$\%\,Error = \frac{Actual\ Load - Forecasted\ Load}{Actual\ Load} \times 100$$

Table -1: Hourly load forecast of 8th May 2013

Time (Hrs.)	Forecasted Temp. (^oC)	Pervious Similar Day Load (MW)	Actual Load (MW)	Fuzzy Forecasted Load (MW)	%Error
1	32	2058	2035	2050.12	-0.714
2	31	2013	2006	2012.73	-0.316
3	30	1983	1989	1982.40	0.329
4	30	1963	1938	1963.11	-1.282
5	30	1933	1935	1932.60	0.136
6	29	1959	1942	1946.50	-0.252
7	29	1902	1900	1901.86	-0.098
8	31	1854	1888	1855.38	1.754
9	32	2018	2013	2018.24	-0.282
10	35	2077	2050	2075.22	-1.238
11	37	2104	2094	2088.68	0.277

12	39	2131	2076	2106.62	-1.476
13	41	2062	2002	2039.94	-1.884
14	42	2079	2050	2061.00	-0.513
15	43	2128	2091	2111.56	-0.960
16	44	2060	2076	2043.73	1.596
17	43	2005	1959	1983.10	-1.204
18	42	1980	1929	1964.19	-1.779
19	39	1914	1930	1915.87	0.745
20	37	2014	2019	2027.16	-0.402
21	37	2021	2038.8	2029.61	0.456
22	36	1967	1975	1999.26	-1.213
23	34	2006	2020	2016.22	0.187
24	33	2066	2100	2086.33	0.655

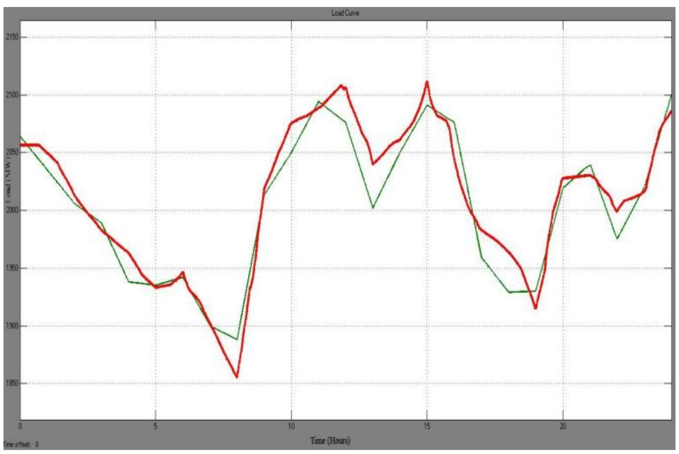

Fig -8: Load curve of 8th May 2013

The results obtained from the fuzzy logic are compared with the conventional method of short term load forecasting and it is found that there is an error is between +2.695659% and -1.884780%. The load curve is plotted which is the comparison between the actual load (green and magenta colour) and the fuzzy forecasted load (red and cyan colour). Figure (Fig -8) and figure (fig -9) shows the load curve plot for 8th May 2013 and 9th May 2013 respectively. From the curve it is observed that fuzzy forecasted load curve is very close to the actual load curve.

Table -2: Hourly load forecast of 9th May 2013

Time (Hrs.)	Forecasted Temp. (^{o}C)	Pervious Similar Day Load (MW)	Actual Load (MW)	Fuzzy Forecasted Load (MW)	%Error
1	31	2015	2056	2060.68	-0.2411
2	30	1988	2020	2033.06	-0.6512
3	29	1947	1981	1991.68	-0.5396
4	28	1923	1970	1968.52	0.0563
5	27	1880	1945	1925.43	1.01495
6	26	1942	1959	1986.72	-1.4300
7	27	1885	1928	1929.83	-0.0797
8	28	1838	1880	1883.22	-0.1819
9	31	2034	2077	2077.99	-0.0295
10	34	2113	2159	2141.08	0.8151
11	36	2136	2145	2170.10	-1.1640
12	39	2133	2165	2154.37	0.4680
13	40	2036	2088	2065.40	1.0629

14	42	2105	2141	2118.66	1.0650
15	43	2122	2187	2144.67	1.9187
16	43	2090	2160	2125.87	1.5781
17	43	2030	2062	2043.28	0.9307
18	42	1971	2043	2005.62	1.8454
19	39	1957	2010	2002.95	0.3383
20	36	2014	2105	2075.03	1.4449
21	34	2025	2072	2094.16	-1.0611
22	33	1989	2102	2045.00	2.6956
23	33	2024	2093	2085.89	0.3560
24	31	2050	2168	2121.64	2.1436

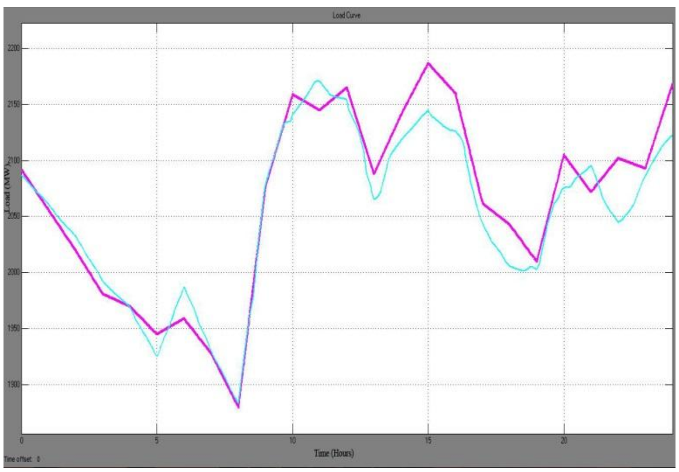

Fig -9: Load curve of 9th May 2013

5. CONCLUSIONS

In this paper fuzzy methodology for short term load forecasting is discussed. It is concluded that using time, temperature and similar previous day load as the inputs and by formulating rule base of fuzzy logic using available data, load forecasting is done with an error margin of +2.695659% and -1.884780%. Moreover, it is also concluded that fuzzy logic approach is very easy for the forecaster to understand as it works on simple “IF-THEN” statements. It also helps in unit commitment decisions, reduce spinning reserve capacity and schedule device maintenance.

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